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MEMORANDUM REPORT No. 1101

OCTOBER 1957

Drag And Stability Properties Of A Redstone Warhead Model (U)

L. C. MacALLISTER

DEPARTMENT OF THE ARMY PROJECT No. 5B03-03-001
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-0108

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MEMORANDUM REPORT NO. 1101

LCMacAllister/iw
Aberdeen Proving Ground, Md.
October 1957

DRAG AND STABILITY PROPERTIES OF A REDSTONE WARHEAD MODEL (U)

ABSTRACT

The drag and stability properties of a Redstone Warhead Model, as determined by range firings, for $0.7 < M < 3.5$ are presented.

SYMBOLS

C_D	Drag coefficient
C_{M_α}	Static moment derivative (per radian)
C_{N_α}	Normal force derivative (per radian)
CP_N	Center of pressure (calibers from base)
C_{m_q}	Damping derivative due to angular velocity
$C_{m_{\dot\alpha}}$	Damping derivative due to yawing velocity

reference area = base area

reference length = base diameter (d)

INTRODUCTION

A version of the Redstone missile Warhead was tested in the Transonic Free Flight Range[1] of the Ballistic Research Laboratories at the request of ABMA. The current model (Fig. 1 and 2) differed from earlier models[2] in that the after body was a single conical section instead of a cone section and a cylinder. The models were encased in a plastic sabot (Fig. 2) and launched through the range from a smooth bored five-inch gun. Sixteen models were launched at speeds from 800 to 4000 fps and all but one model traversed the full range of instrumentation. A summary of the initial firing data and the physical measurements of the model are given in Table I.

RESULTS

The range data were processed by the usual techniques[3] and the reduction and motion parameters are given in Table II. The resulting aerodynamic coefficients are given in Table III.

The drag coefficient, C_D, is shown in Figure 3. The curve shown is for zero yaw. A value of $C_{D_{\overline{\delta^2}}}$ of 2.5 per squared radians has been used to reduce the individual round values to a zero yaw value. This value of $C_{D_{\overline{\delta^2}}}$ seems adequate for the supersonic data.

The moment derivative, C_{M_α}, (for a center of mass position 2.47 calibers forward of base) is given in Figure 4. Maximum stability occurs at about M = 0.9 and decreases with increasing Mach number. In fact, extrapolation would give a neutral point at about M = 6; however, the slope of the C_{m_α} curve may change at speeds above those tested. The normal force slope is shown in Figure 5 and the center of pressure of the normal force in Figure 6.

The damping moment derivatives, $(C_{m_q} + C_{m_{\dot\alpha}})$, Figure 7, are stabilizing except at high subsonic speeds. For Mach numbers greater than about 1.1 $(C_{m_q} + C_{m_{\dot\alpha}})$ is fairly constant and adequately large.

Representative shadowgraphs of the model in flight are given in Figure 8 to 16. It might be noted that even at the lowest test speed ($M \doteq 0.7$) small shock waves exist at the corner of the nose cone, hence these data do not represent a fully subsonic local flow state. Also, almost all of the variations of the model's properties, except slow trends, occur in the region from the

lowest speed tested up to about $M \doteq 1.2$ where full supersonic flow appears to be established over the body and the control vanes.

REMARKS

Normally in the processing of range data from a statically stable symmetric missile which is not spinning and has a linear force system certain equalities of the reduction parameters are preserved. Primarily these are equality in magnitude of the epicyclic rates, b_1 and b_2. It can be noted in Table II that these equalities are not always present to within the probable accuracy of the data. Generally this can be ascribed to three causes:

1. Small size of one of the epicyclic modes, a degenerate fitting condition, i.e., rounds 2-4471 and 2-4476. These may be handled by computing the properties utilizing the equalities and the significant mode.

2. Small missile asymmetries where impossible, or impractical, to process by asymmetric reduction systems. The highest velocity rounds are most apt, mechanically, to have suffered some slight damage.

3. Nonlinearity of the aerodynamic force system. This is partially allowed for but may be the only logical reason why the data for the low Mach number rounds has inconsistent damping for the two modes.

L.C. MacAllister

L. C. MacALLISTER

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1. Rogers, W. K., The Transonic Free Flight Range, BRL Report No. 849, 1953.
2. Rogers, W. K., Free Flight Tests of A Model of The "Redstone", XSSM-A-14, Warhead, BRLM 885, 1955. AD - 69 214
3. Murphy, C. H., Data Reduction for Free Flight Ranges, BRL Report 900, 1956. ?
AD - 35 833

TABLE I

Test Conditions

Round Number	Date 1957	Mid Range Test Velocity fps	Weight lb	C. G. in. from base	Remarks
2-4431	2 March	3450	8.11		
2-4432	2 March	1280	8.08		
2-4433	2 March	830	8.10	7.413	
2-4470	18 March	1250	8.11	7.422	
2-4471	18 March	1470	8.10	7.515	
2-4472	18 March	1600	8.11	7.420	Hit fragment shield in second group
-4473	18 March	1600	8.10	7.416	
2-4474	20 March	2770	8.08	7.404	
2-4475	20 March	2430	8.09	7.412	
2-4476	20 March	3060	8.09	7.410	
2-4479	27 March	810	8.09	7.414	
2-4480	27 March	810	8.11	7.414	
2-4481	27 March	920	8.10	7.414	
2-4482	28 March	1050	8.10	7.414	
2-4483	28 March	1100	8.09	7.414	
2-4484	28 March	3990	8.10	7.413	

Average maximum diameter (20 measurements) $= 3.000 \left({}^{+.002}_{-.001}\right)$

Average length (20 measurements) $= 14.397 \left({}^{+.006}_{-.017}\text{in}\right)$

Average axial mement of inertia (2 measurements) $= 6.39$ lb-in^2

Average transverse moment of inertia (2 measurements) $=101.50$ lb-in^2

TABLES II

REDUCTION AND MOTION PARAMETERS

Round Number	Mach Number	$\overline{\delta^2}$	Epicyclic Yaw Rates (deg/ft)		Model Damping Rates (1/ft)		Mid-range values of yaw arms (rad)		Standard Error Yaw Fit	Standard Error Swerve Fit
		(deg^2)	b_1	b_2	$\lambda_1 10^3$	$\lambda_2 10^3$	K_1	K_2	rad	feet
2-4479	.717	11.2	-1.853	1.932	- .45	- .05	.0248	.0529	.0030	.020
2-4480	.720	9.8	-1.909	+1.897	+1.02	- .47	.0325	.0424	.0048	.041
2-4481	.814	5.9	-1.999	+2.031	+ .44	+ .32	.0303	.0292	.0029	.020
2-4482	.921	22.5	-2.198	+2.17	1.21	+1.40	.0291	.0904	.0045	.015
2-4483	.971	7.7	-2.031	+2.058	1.10	+1.57	.0210	.0394	.0046	[illegible]
2-4470	1.110	5.3	-1.865	+1.848	1.65	+1.59	.0260	.0254	.0027	.018
2-4471	1.302	1.4	-1.449	+1.785	1.56	+3.96	.0169	.0052	.0020	.016
2-4473	1.436	15.0	-1.339	+1.371	1.18	+1.64	.0298	.0547	.0042	.031
2-4475	2.159	4.1	-1.138	+1.116	1.65	+1.46	.0244	.0212	.0016	.022
2-4474	2.465	9.4	-1.129	+1.032	1.60	+1.62	.0315	.0325	.0027	.012
2-4476	2.714	1.2	-1.061	+1.000	2.09	+1.47	.0081	.0156	.0033	.025
2-4484	3.453	5.0	-0.904	+0.904	2.29	2.29	.0238	.0216	.0058	.061

TABLE III

AERODYNAMICS COEFFICIENTS

Mach Number	Reynolds Number (10^{-6})	$\overline{\delta^2}$ (deg^2)	C_D	C_{M_α} (per rad)	C_{N_α}	CP_N (from base)	$C_{M_q} + C_{M_{\dot\alpha}}$	Round Number
.717	1.25	11.2	.2801	-1.668	3.79	2.03	4.1	2-4479
.722	1.26	9.8	.2801	-1.685	3.63	2.01	8.5	2-4480
.737	0		.2758					
.814	1.42	5.9	.2956	-1.890	3.06	1.85	-2.3	2-4481
.921	1.61	22.5	.3998	-2.217	3.44	1.83	-24.5	2-4482
.971	1.70	7.7	.4395	-1.939	5.14	2.09	-20.6	2-4483
1.110	1.93	5.3	.5485	-1.610	4.48	2.11	-30.2	2-4470
1.302	2.27	1.4	.5024	-1.215	<u>4.08</u>	<u>2.17</u>	<u>-59.0</u>	2-4471
1.430	2.51	15.2	.4966	- .858	3.32	2.21	-28.0	2-4473
2.159	3.73	4.1	.3845	- .601	3.46	2.30	-30.9	2-4475
2.465	4.29	9.4	.3456	- .547	3.28	2.30	-32.2	2-4474
2.714	4.68	1.2	.3163	- .504	3.86	2.34	-35.1	2-4476
3.05		0	.2872					
3.453	6.02	5.0	.2633	- .388	2.73	2.33	49.9	2-4484

Underlined values are poorly determined due to small yaw size.

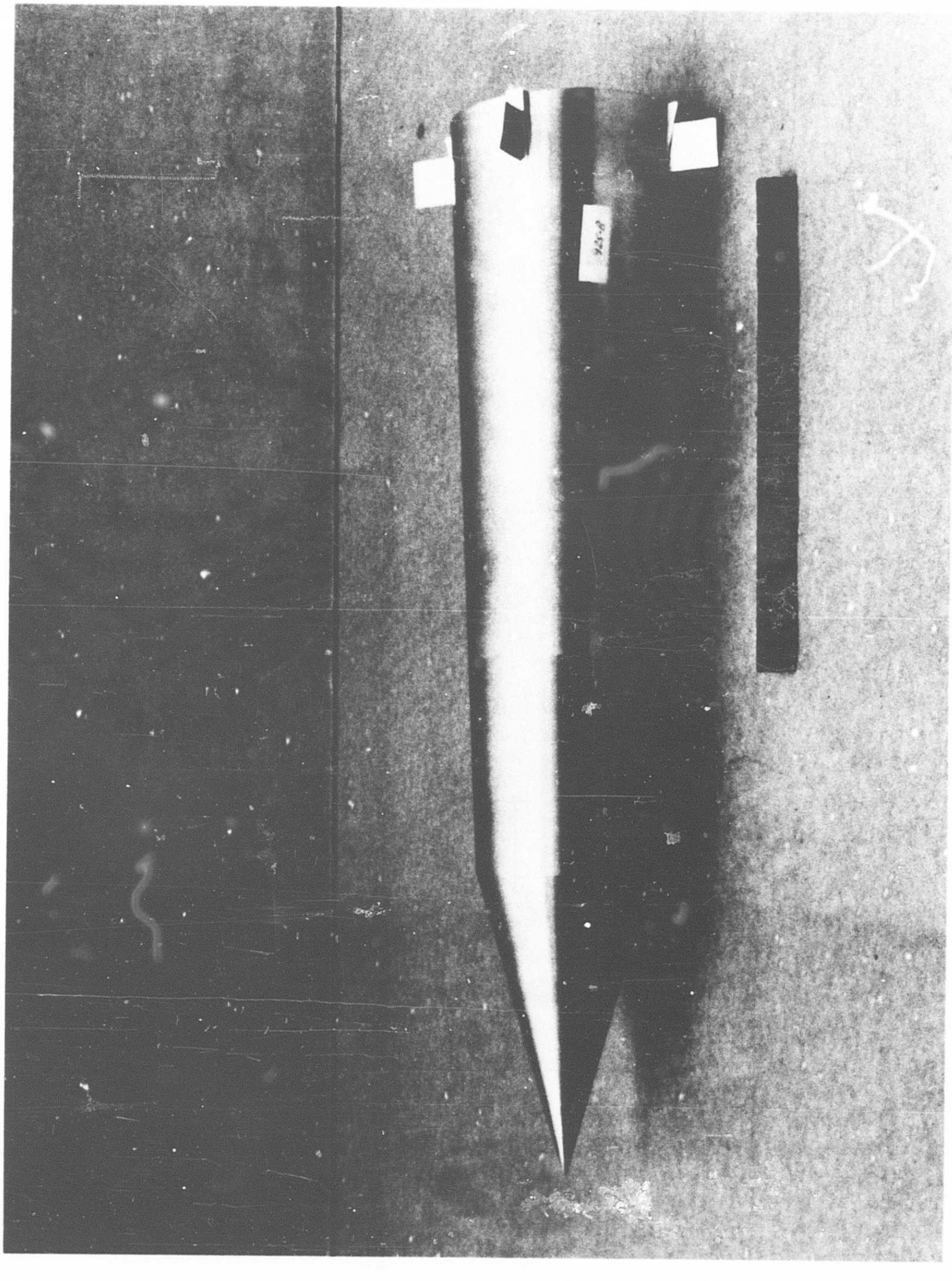

FIGURE I RANGE MODEL

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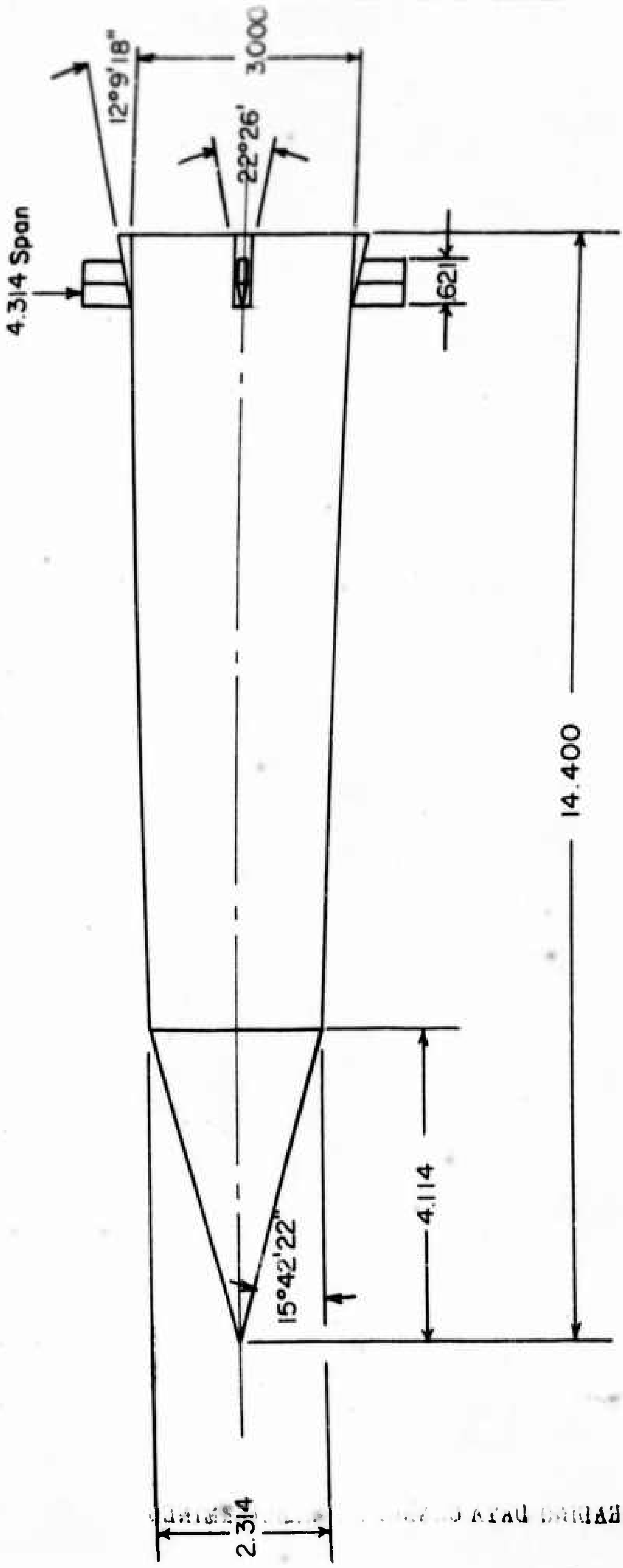
REDSTONE WARHEAD



NOTE: All Dimensions are in Inches

FIGURE 1a

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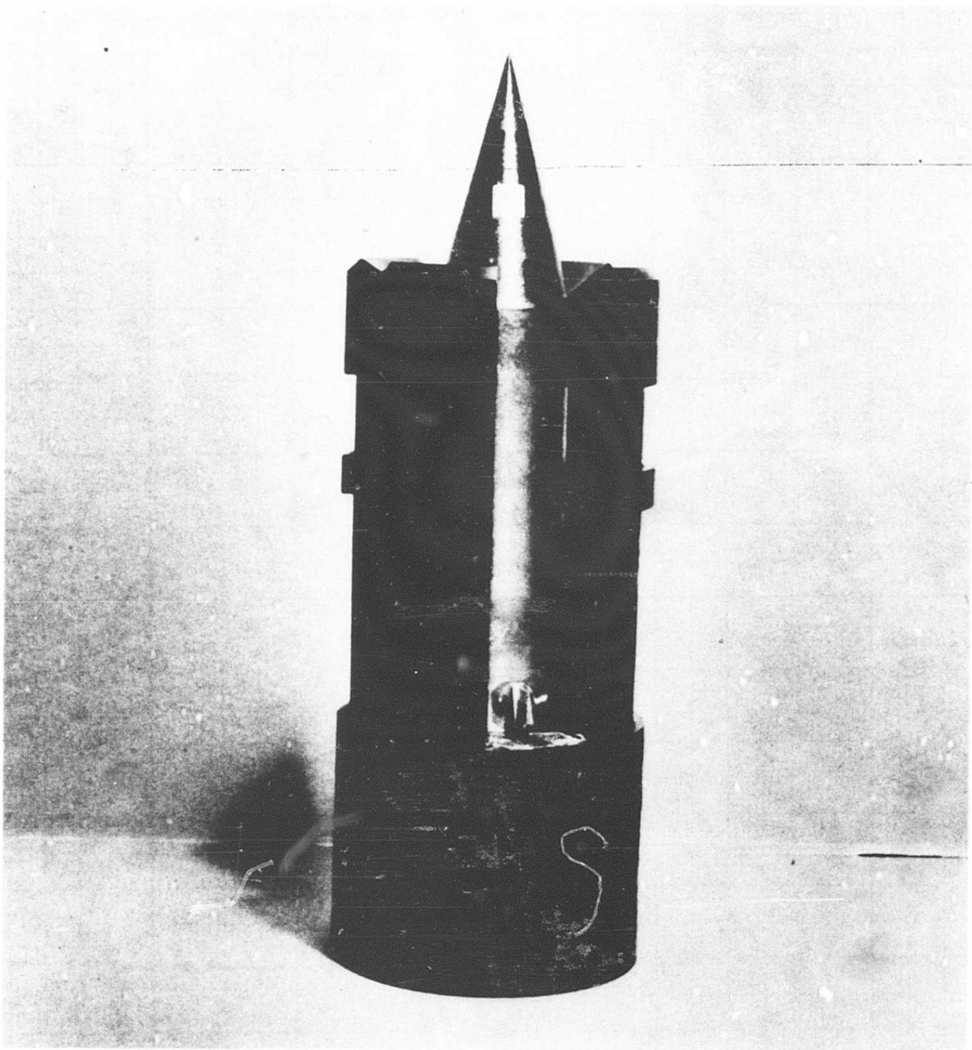
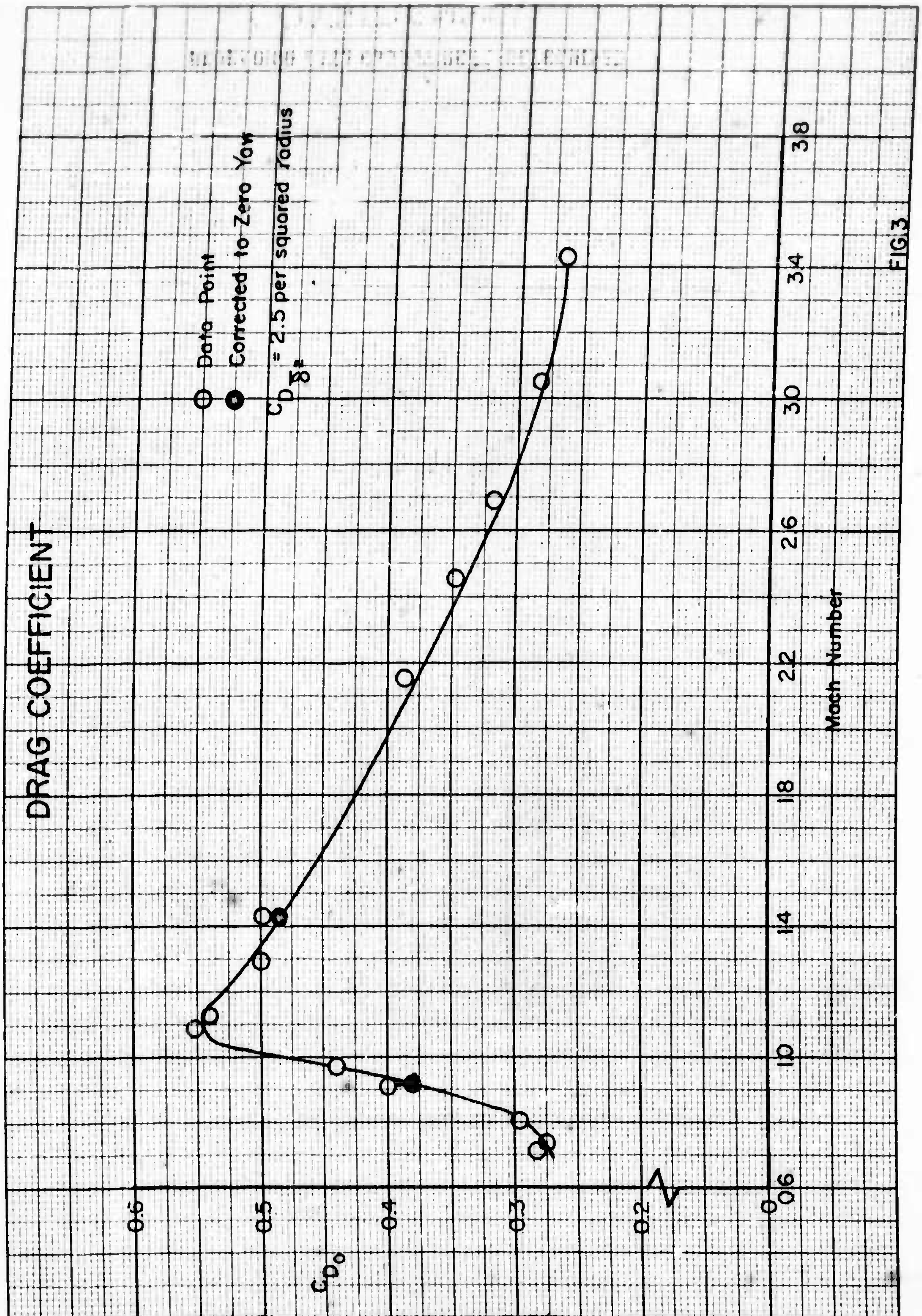
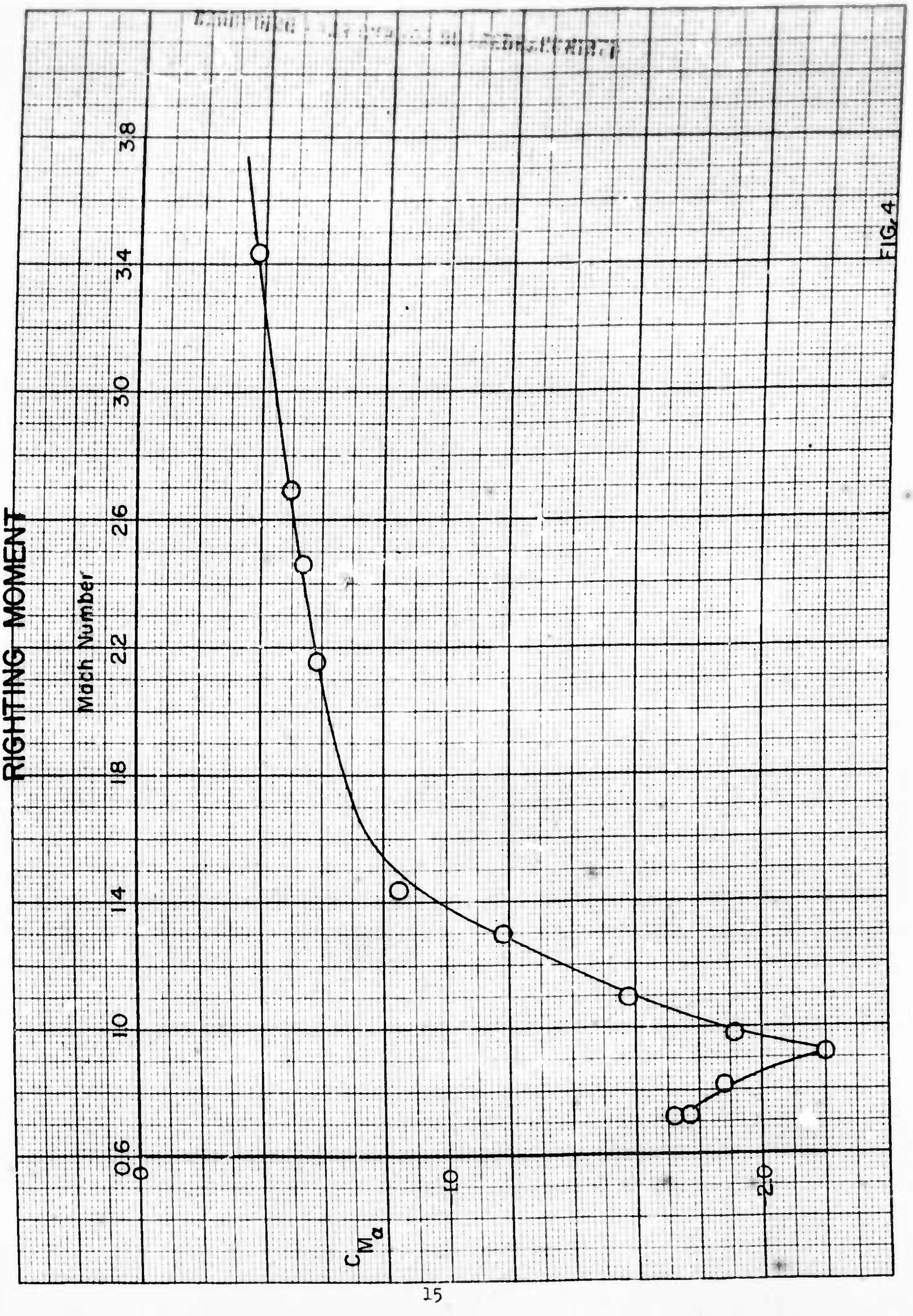
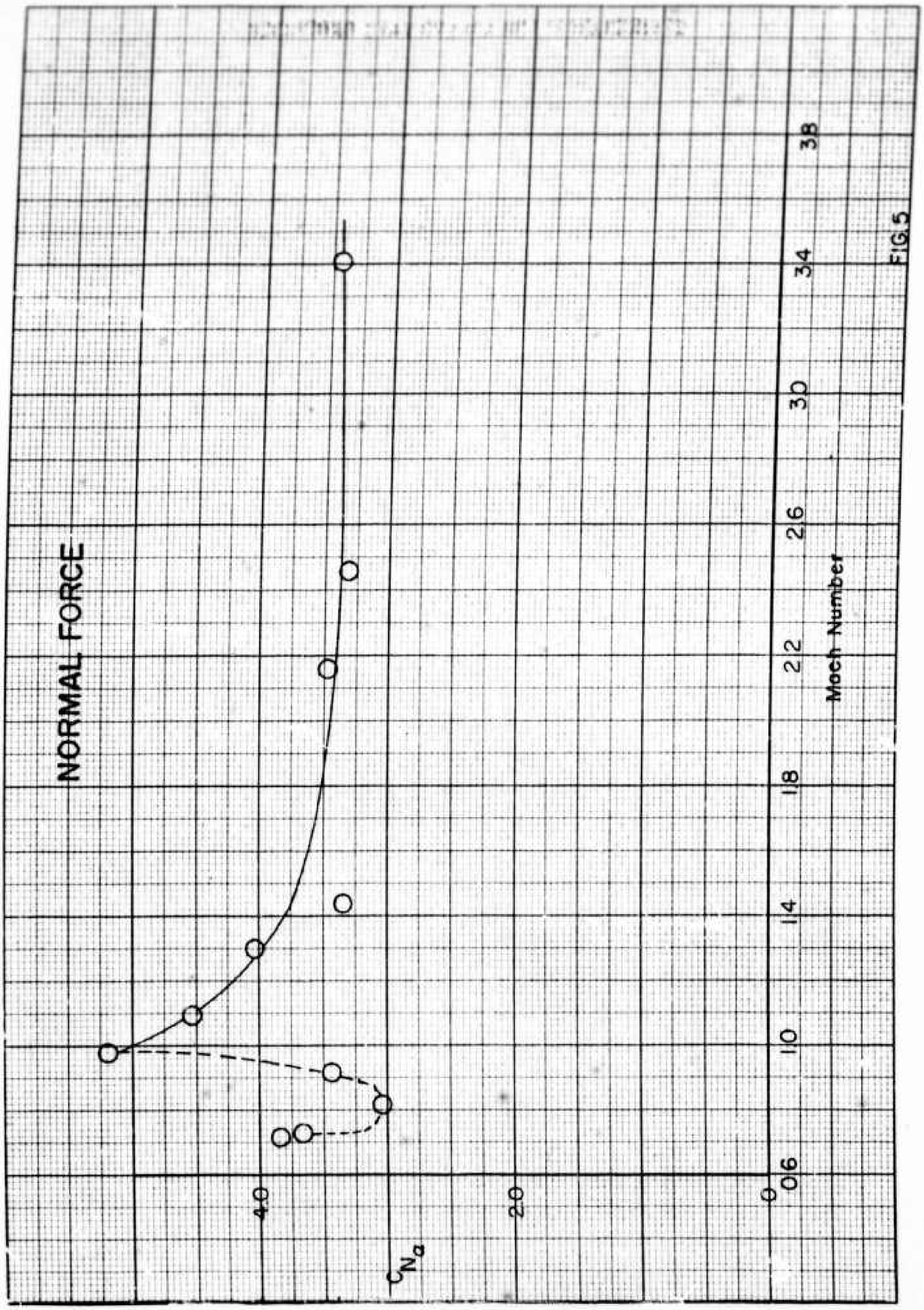
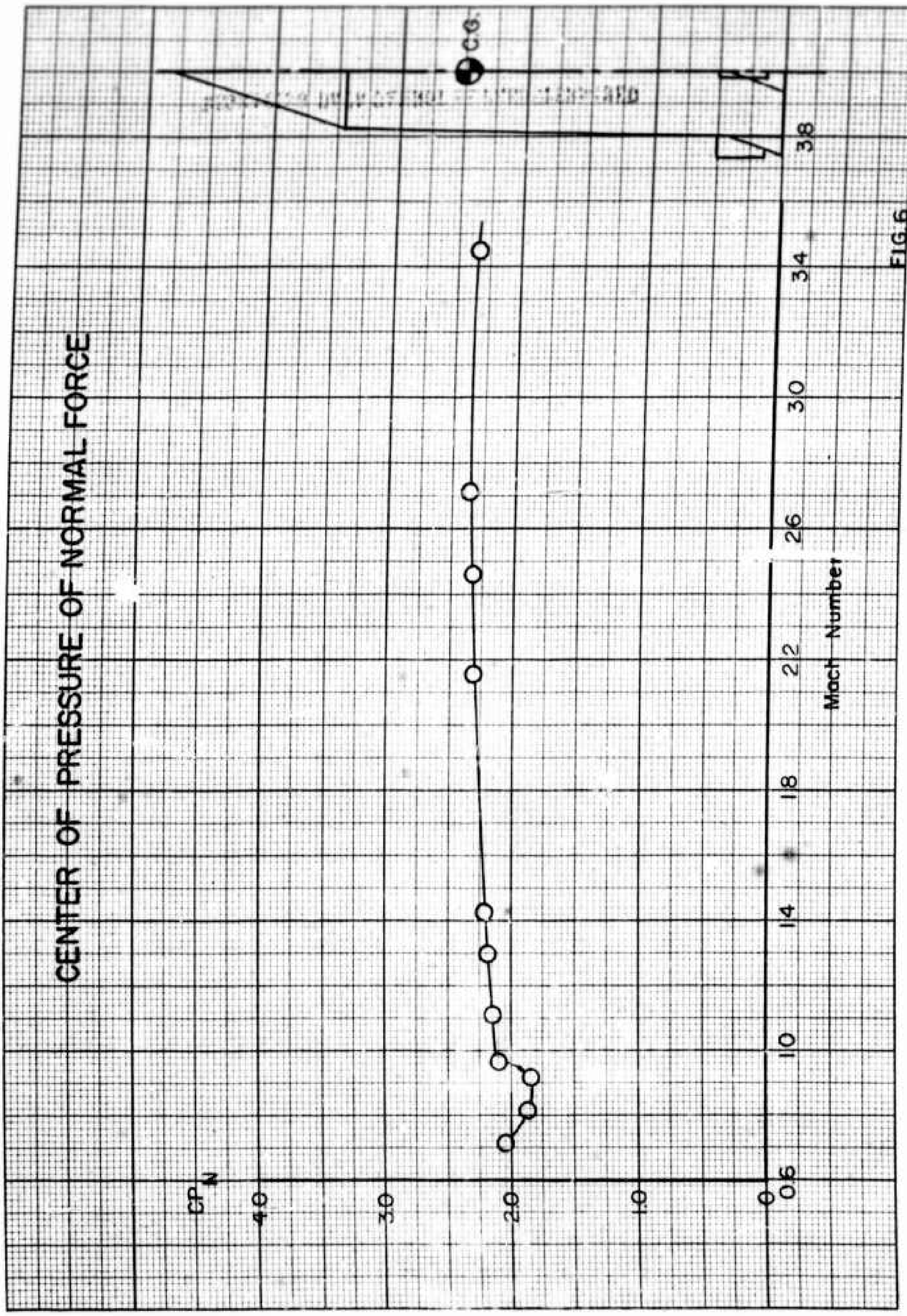


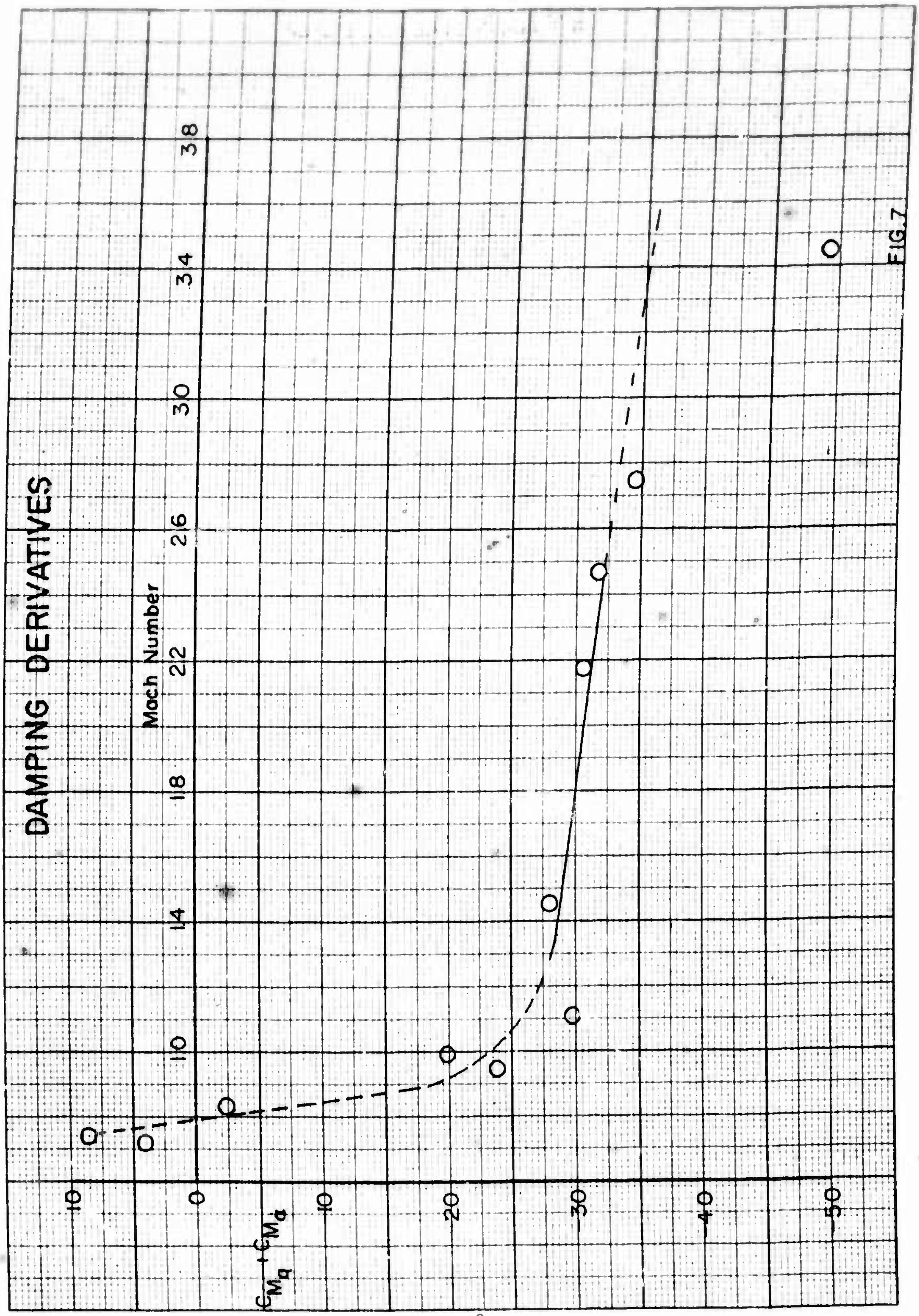
FIGURE 2 TYPICAL RANGE MODEL IN SABOT


DRAG COEFFICIENT
Data Point
Corrected to Zero Yaw
$C_{D_{\delta^2}}$ = 2.5 per squared radius
C_{D_0}
0.6
0.5
0.4
0.3
0.2
0
06
10
14
18
22
26
30
34
38
Mach Number
FIG.3


RIGHTING MOMENT
Mach Number
0.6
1.0
1.4
1.8
2.2
2.6
3.0
3.4
3.8
0
1.0
2.0
C_{M_α}
FIG. 4


NORMAL FORCE
4.0
2.0
0
C_{N_α}
06
10
14
18
22
26
30
34
38
Mach Number
FIG.5


CENTER OF PRESSURE OF NORMAL FORCE
C.G.
CP N
4.0
3.0
2.0
1.0
0
.6
10
14
18
22
26
30
34
38
Mach Number
FIG. 6


DAMPING DERIVATIVES
Mach Number
10
14
18
22
26
30
34
38
10
0
10
20
30
40
50
$C_{M_q} + C_{M_{\dot{\alpha}}}$
FIG. 7

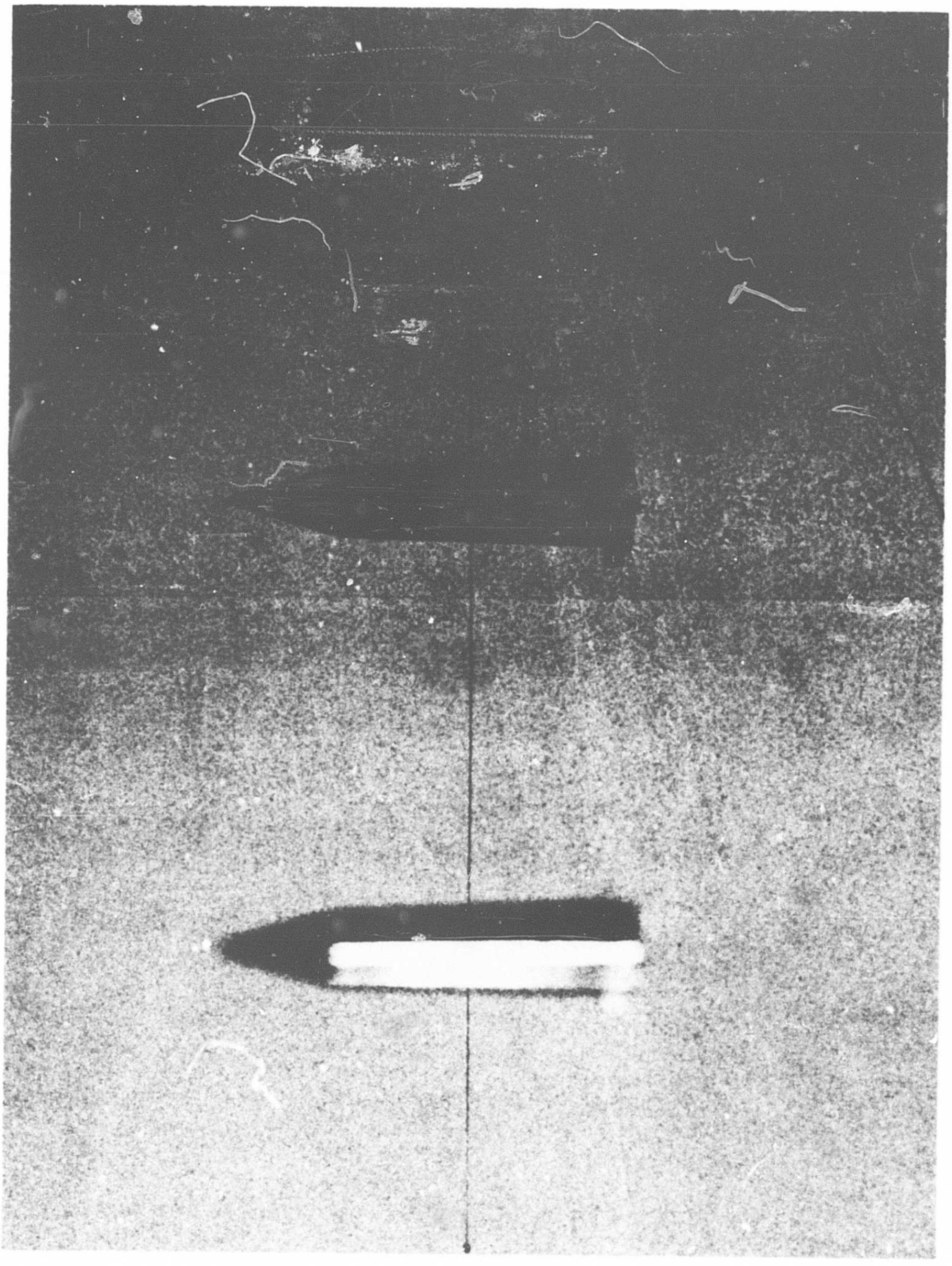


FIGURE 8 SHADOWGRAPH M ≐ 0.72

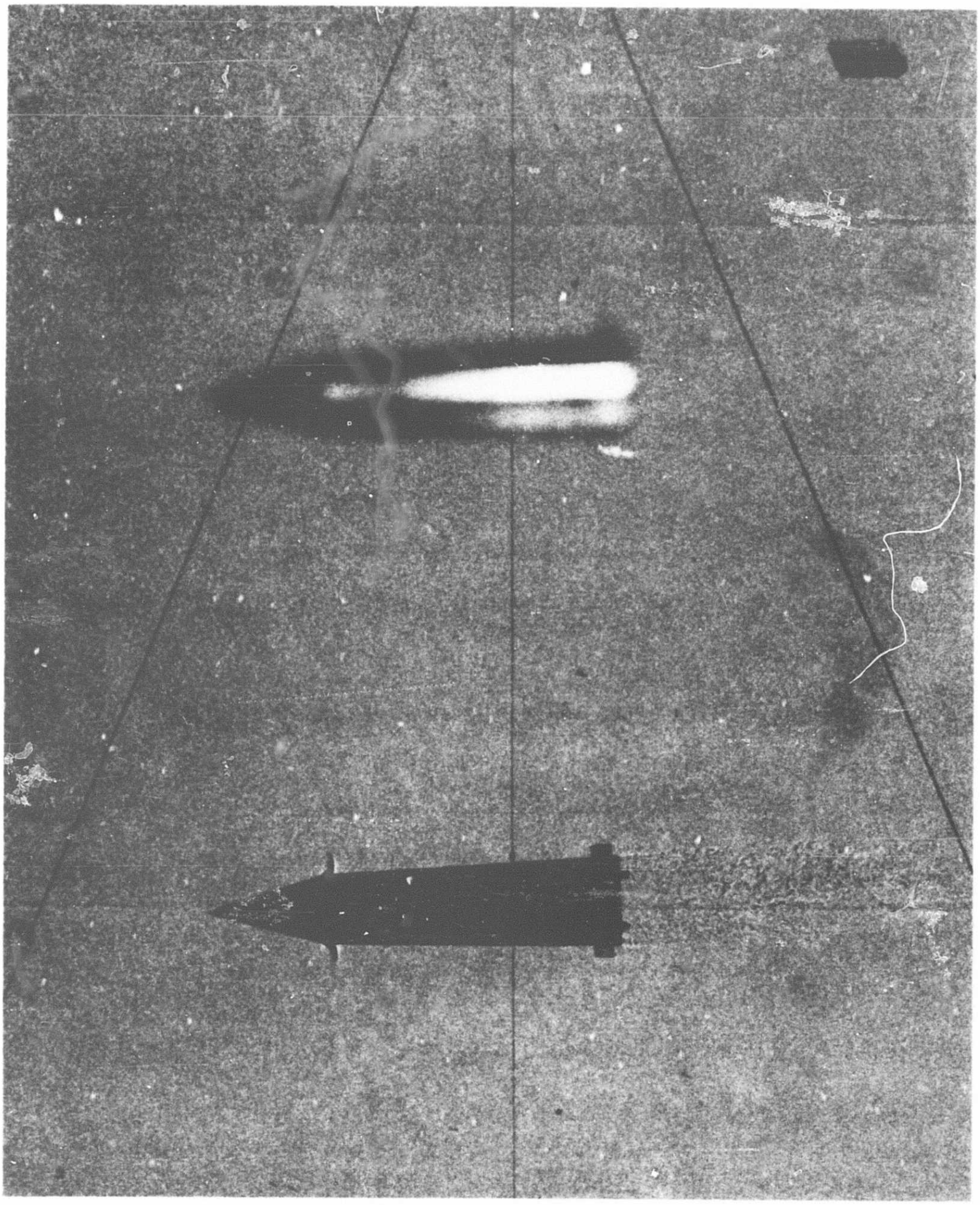


FIGURE 9 SHADOWGRAPH M ≐ 0.81

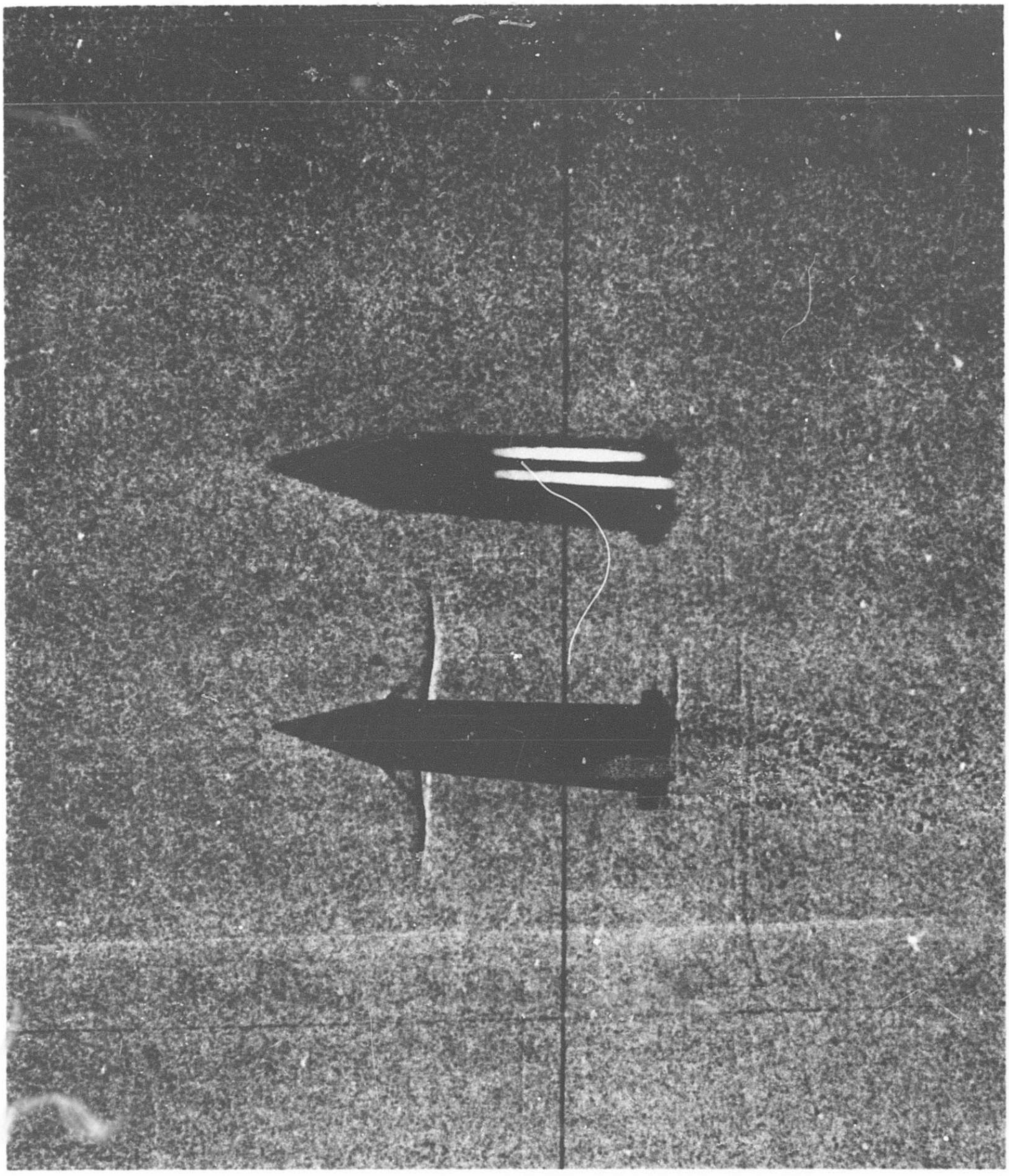


FIGURE 10 SHADOWGRAPH M ≐ 0.92

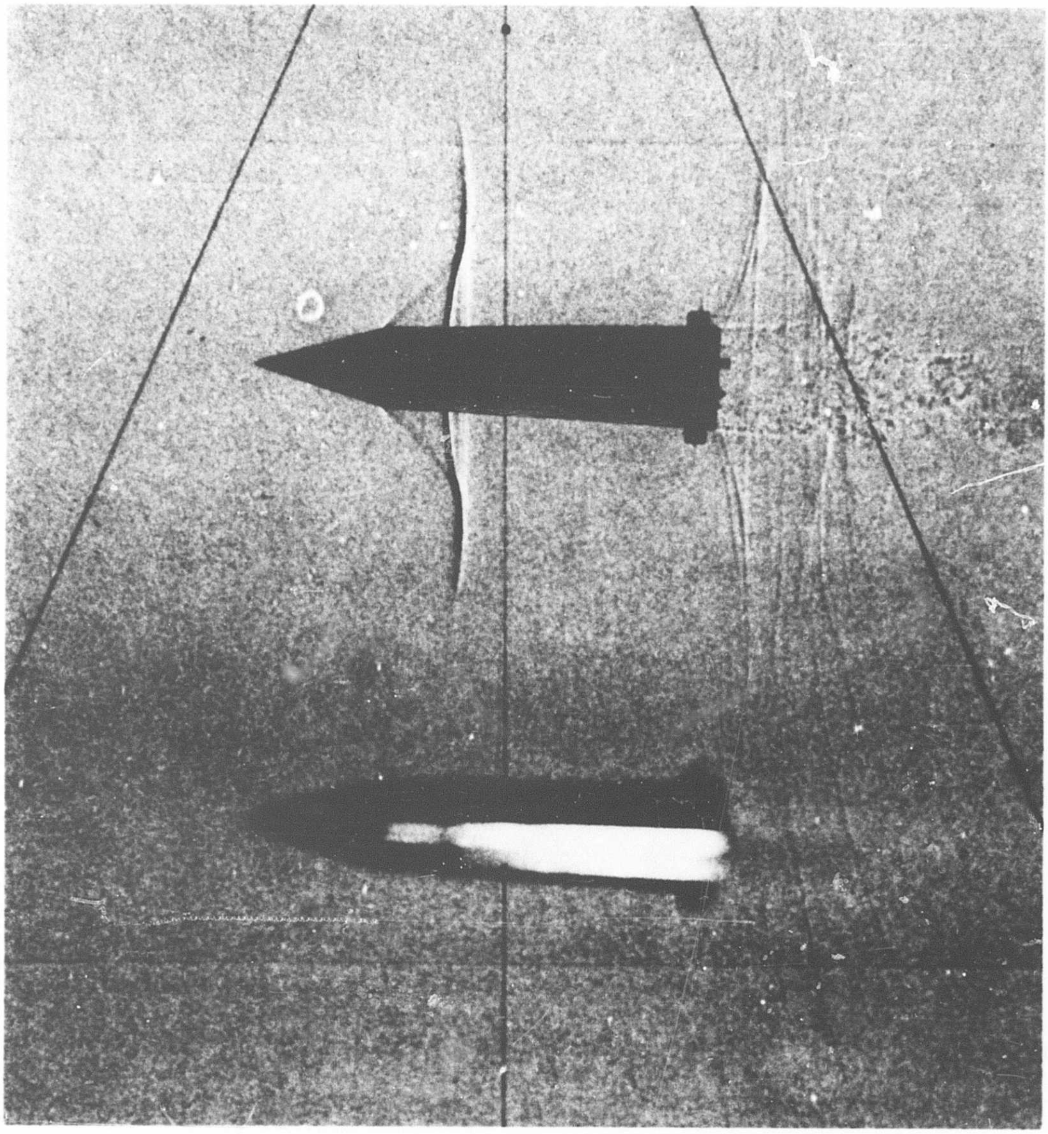


FIGURE 11 SHADOWGRAPH M≐ 0.97

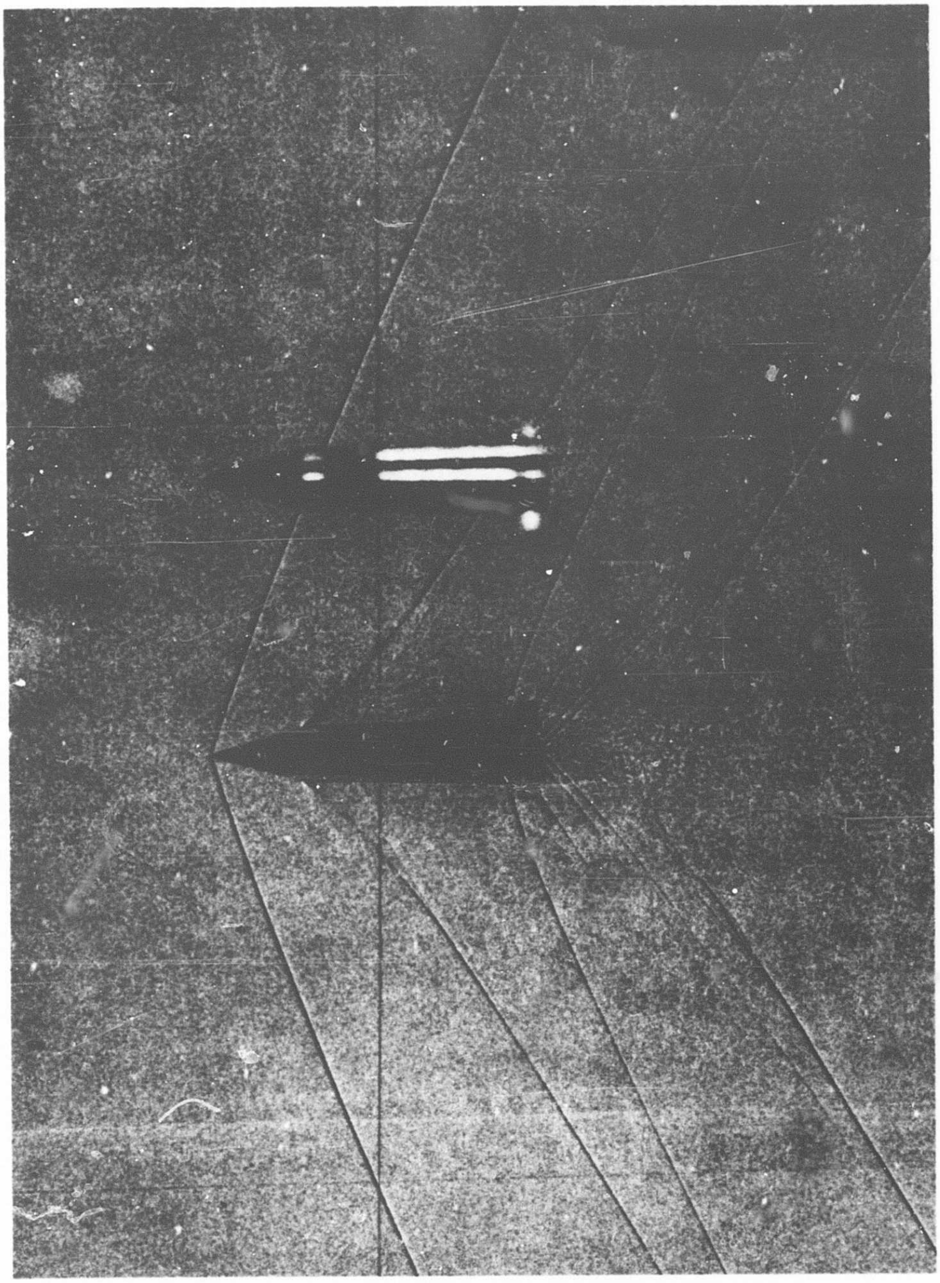


FIGURE 12 SHADOWGRAPH $M \doteq 1.11$

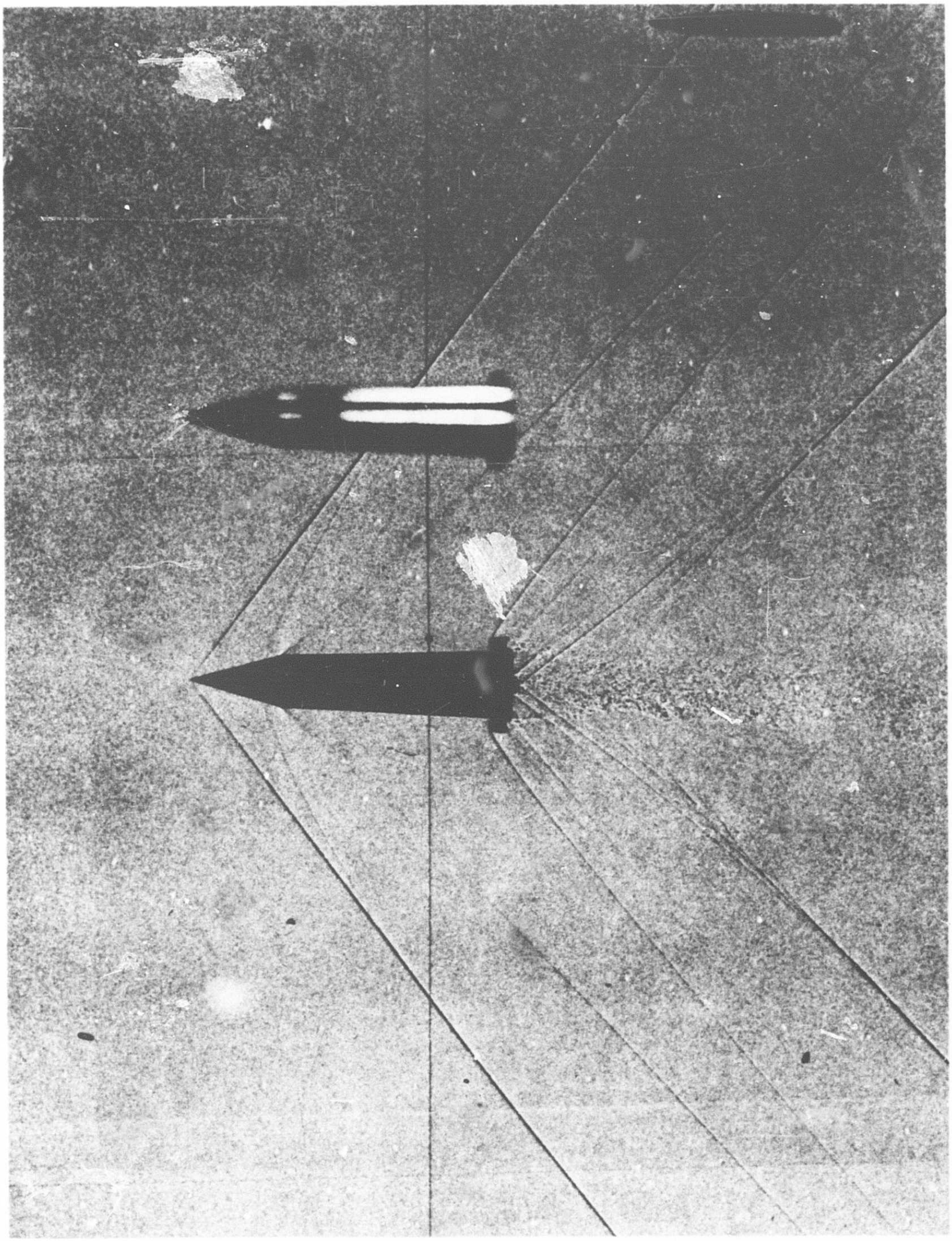


FIGURE 13 SHADOWGRAPH M ≐ 1.30

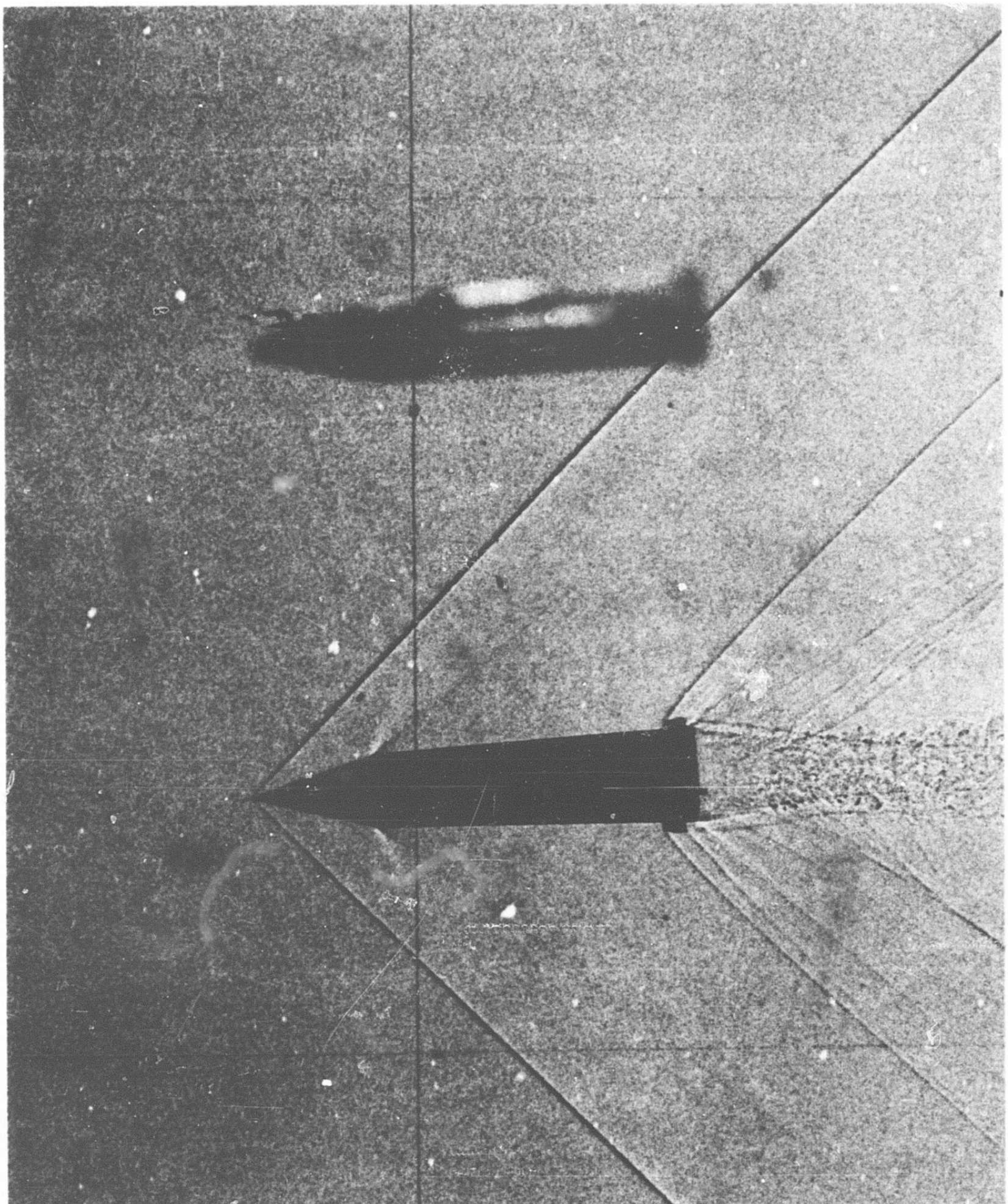


FIGURE 14 SHADOWGRAPH M ≐ 1.52

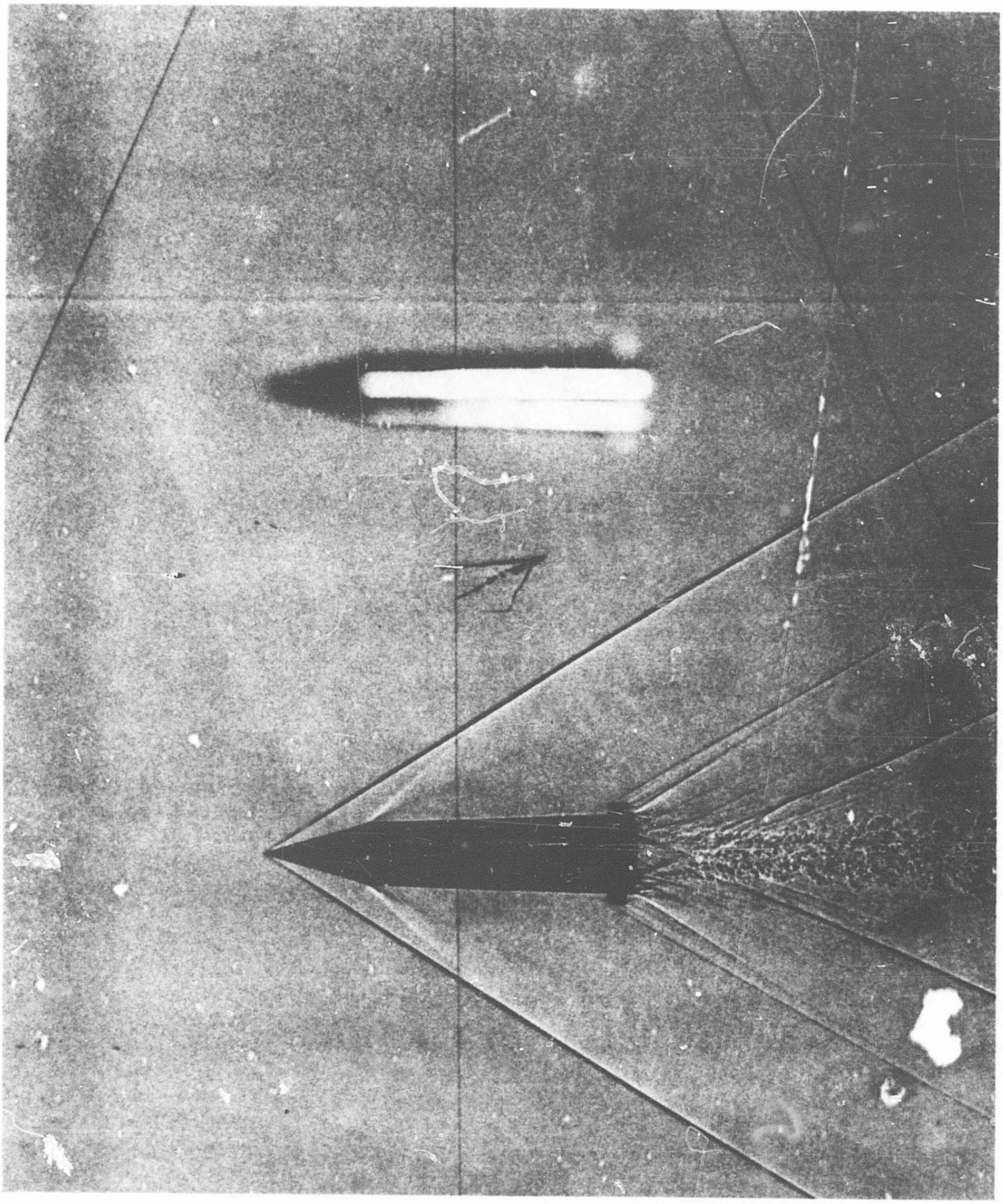


FIGURE 15 SHADOWGRAPH M ≐ 2.16

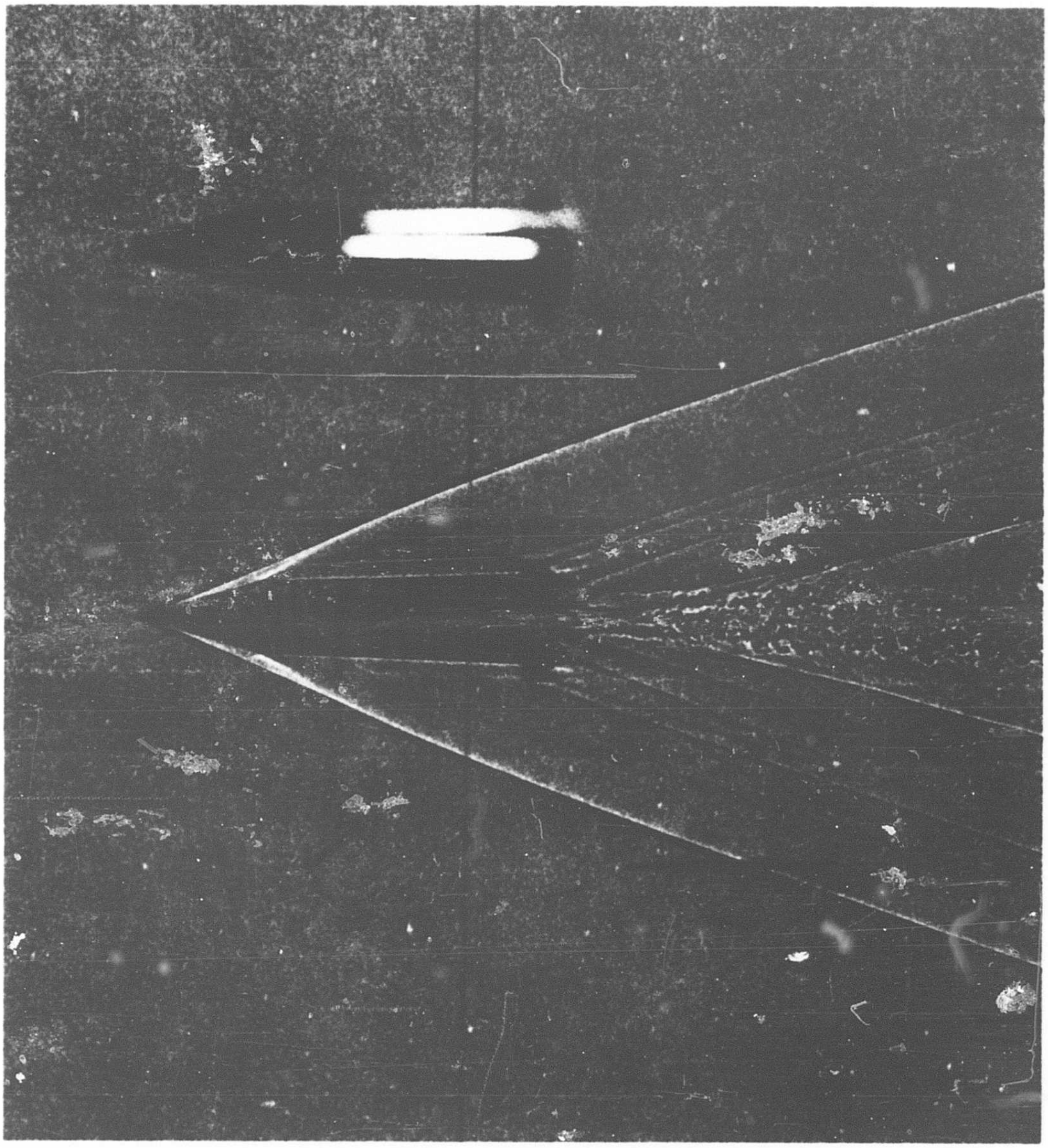


FIGURE 16 SHADOWGRAPH M ≐ 3.45

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